(No Model.)

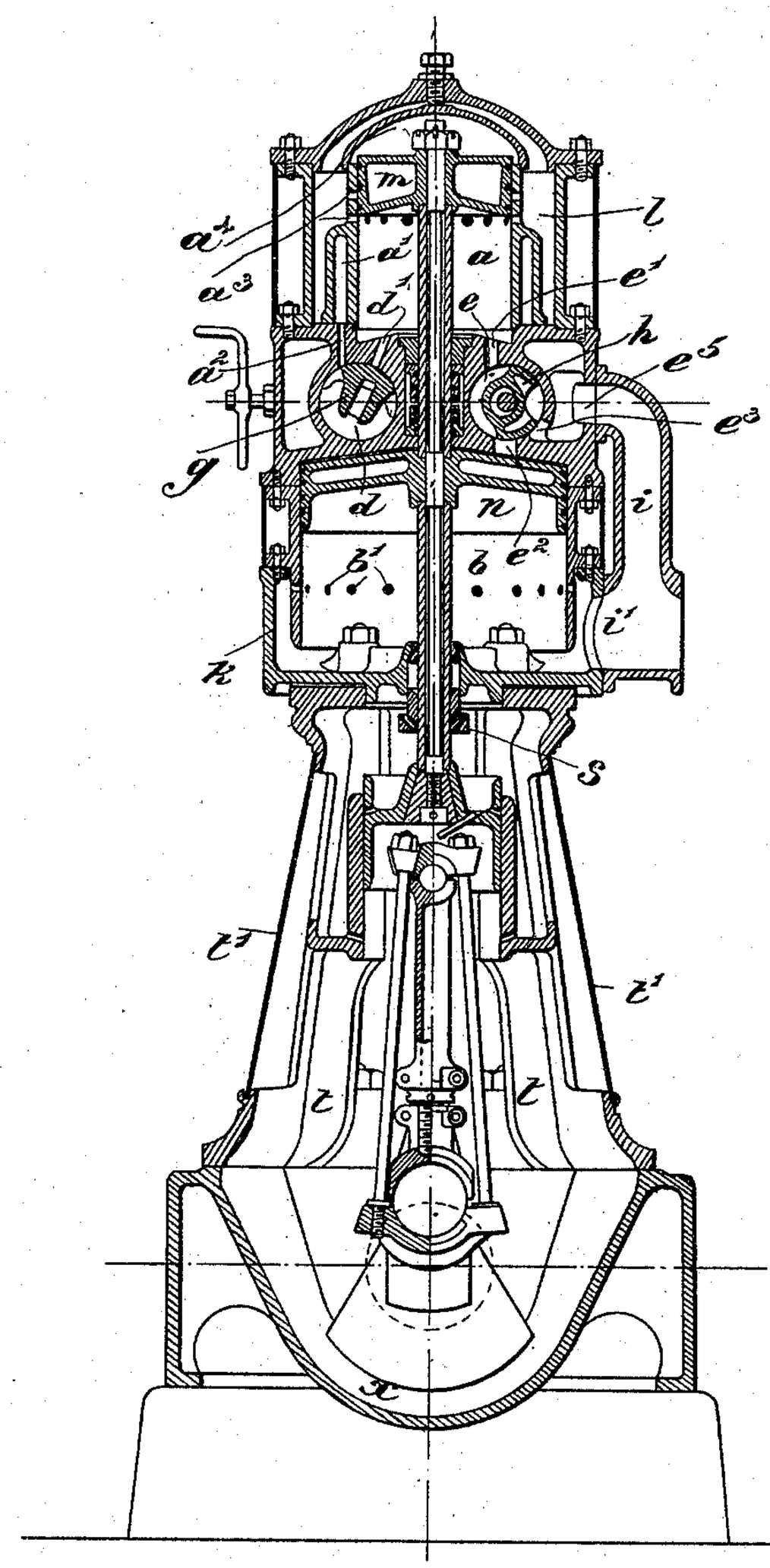
5 Sheets—Sheet 1.

J. S. RAWORTH.

STEAM ENGINE.

No. 584,704. Patented June 15, 1897.

Fig. 1.



Witnesses.

Geo. E. Fuch

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Inventor:

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by Pattison Nesbit

Atty.

(No Model.)

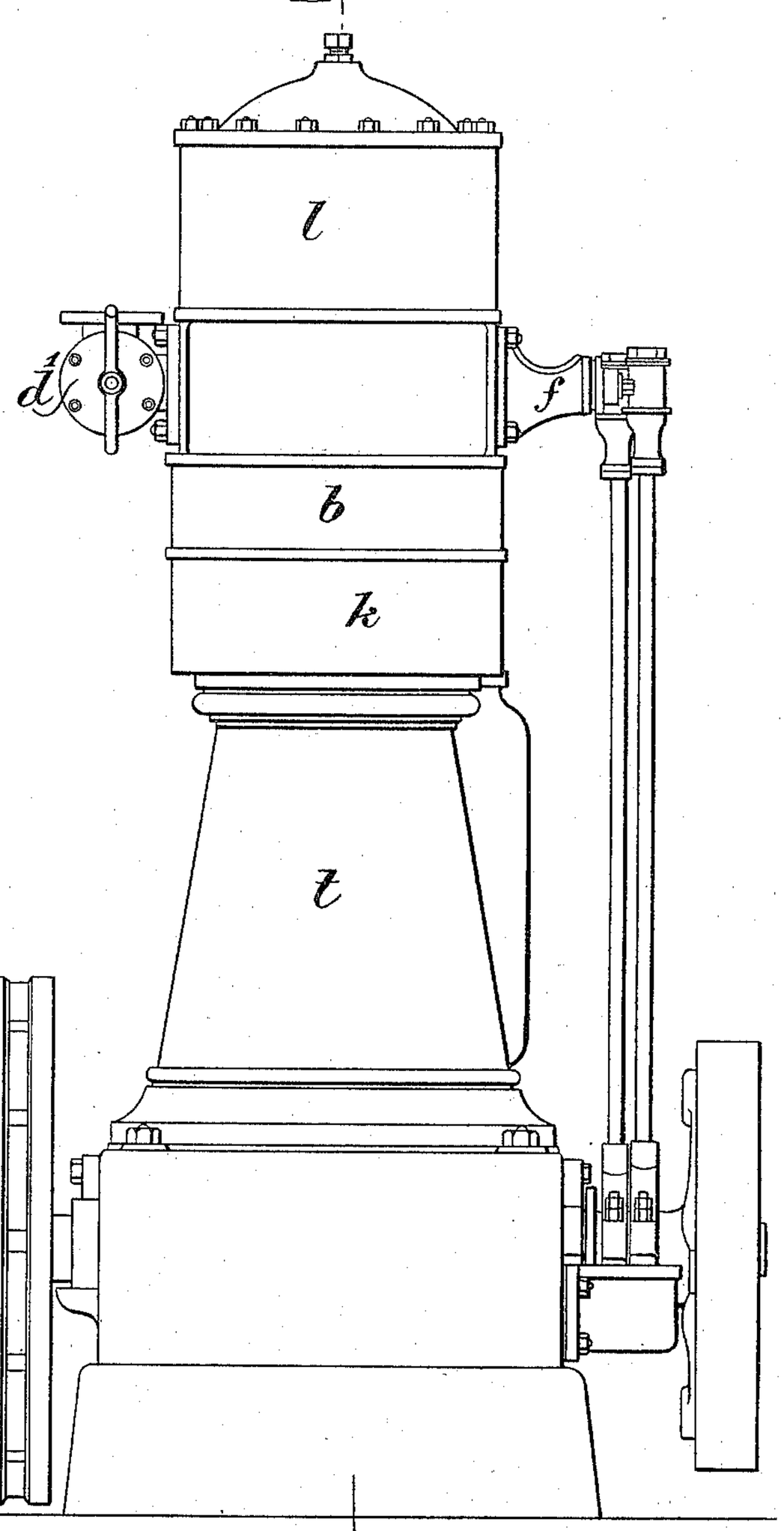
5 Sheets—Sheet 2.

J. S. RAWORTH.

STEAM ENGINE.

No. 584,704. Patented June 15, 1897.

Fig. 2.



Witnesses.

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5 Sheets—Sheet 3.

J. S. RAWORTH.

STEAM ENGINE.

No. 584,704. Patented June 15, 1897.

Fig. 4.

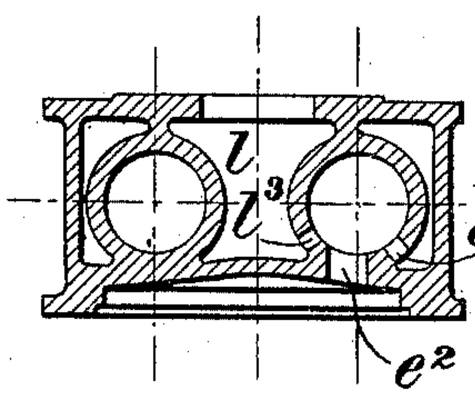


Fig. 3.

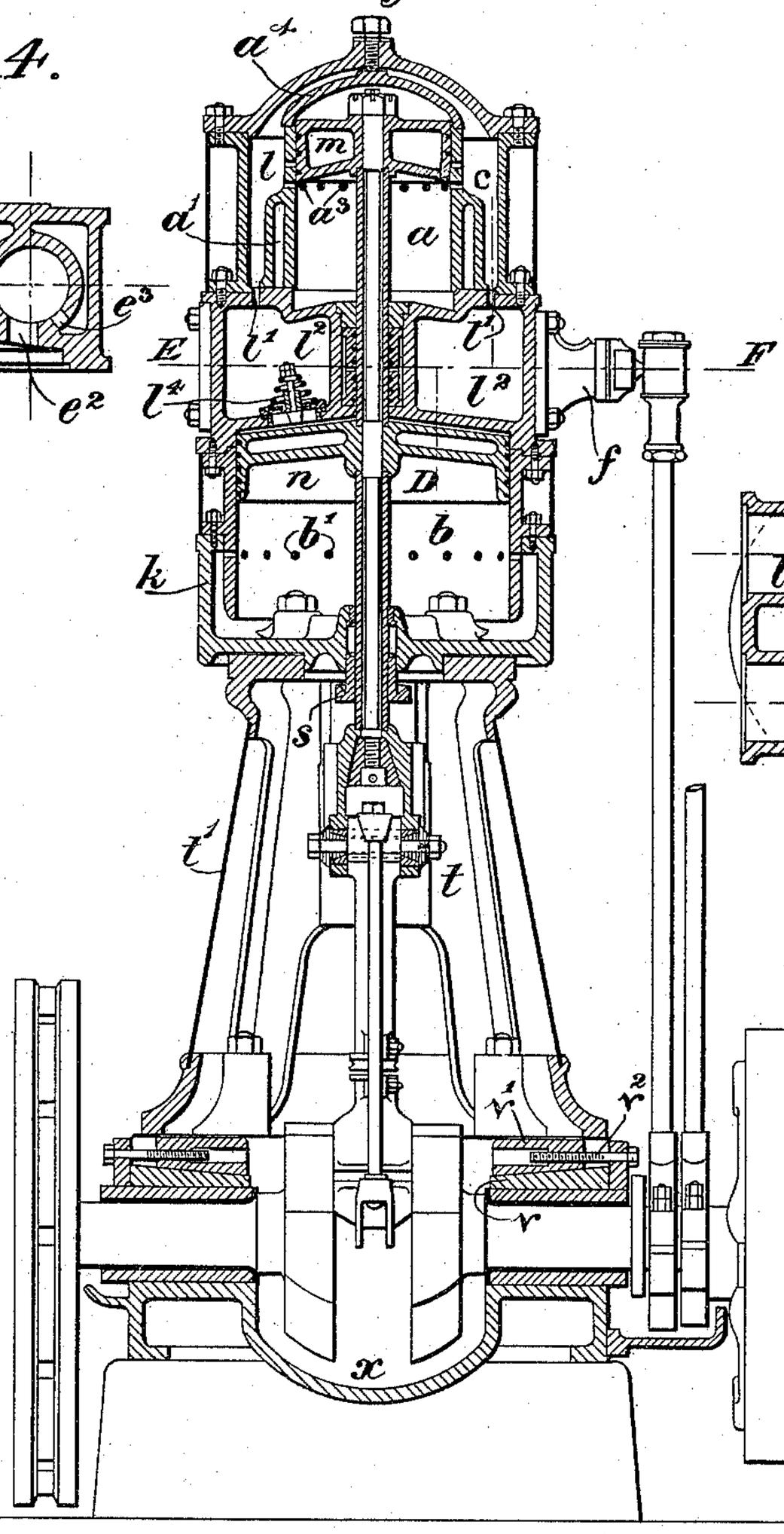
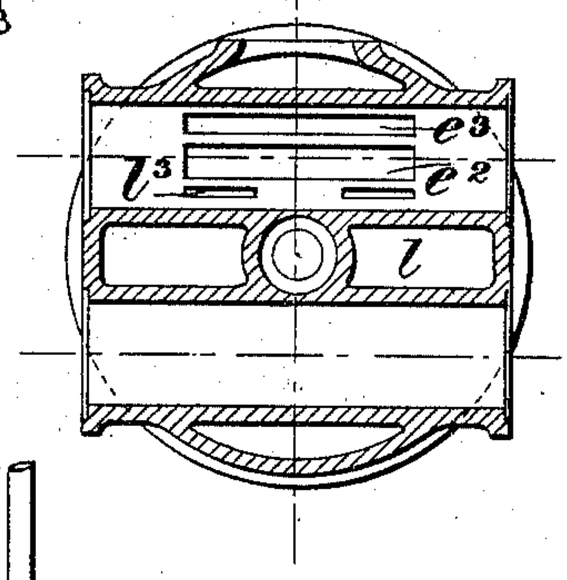


Fig. 5.



Witnesses.

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5 Sheets—Sheet 4.

J. S. RAWORTH.

STEAM ENGINE.

No. 584,704. Patented June 15, 1897.

Fig. 6.

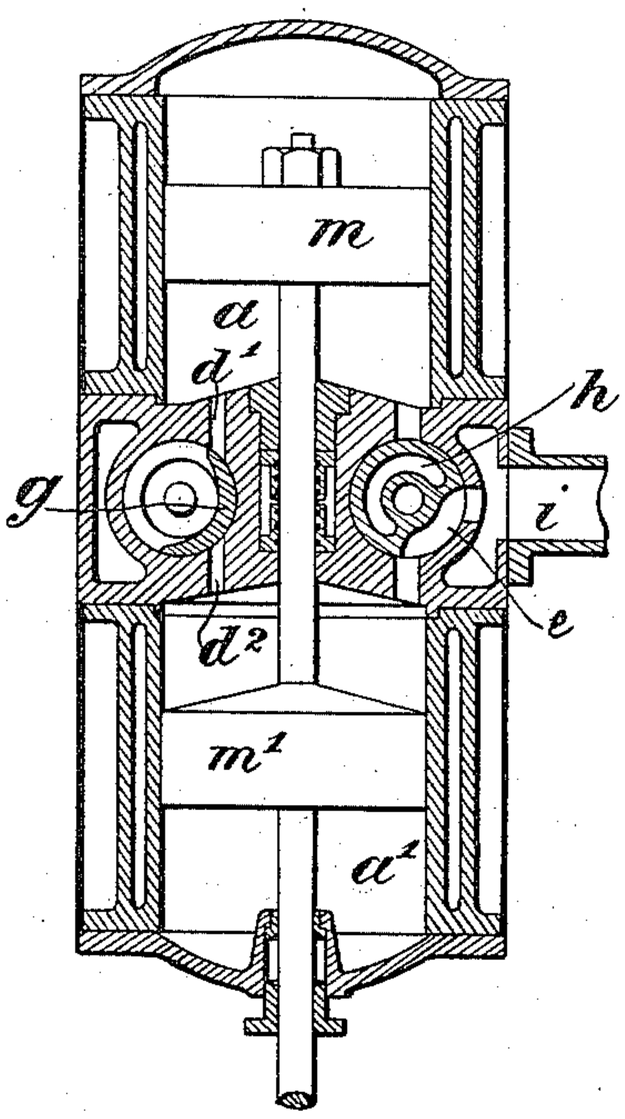


Fig. 7.

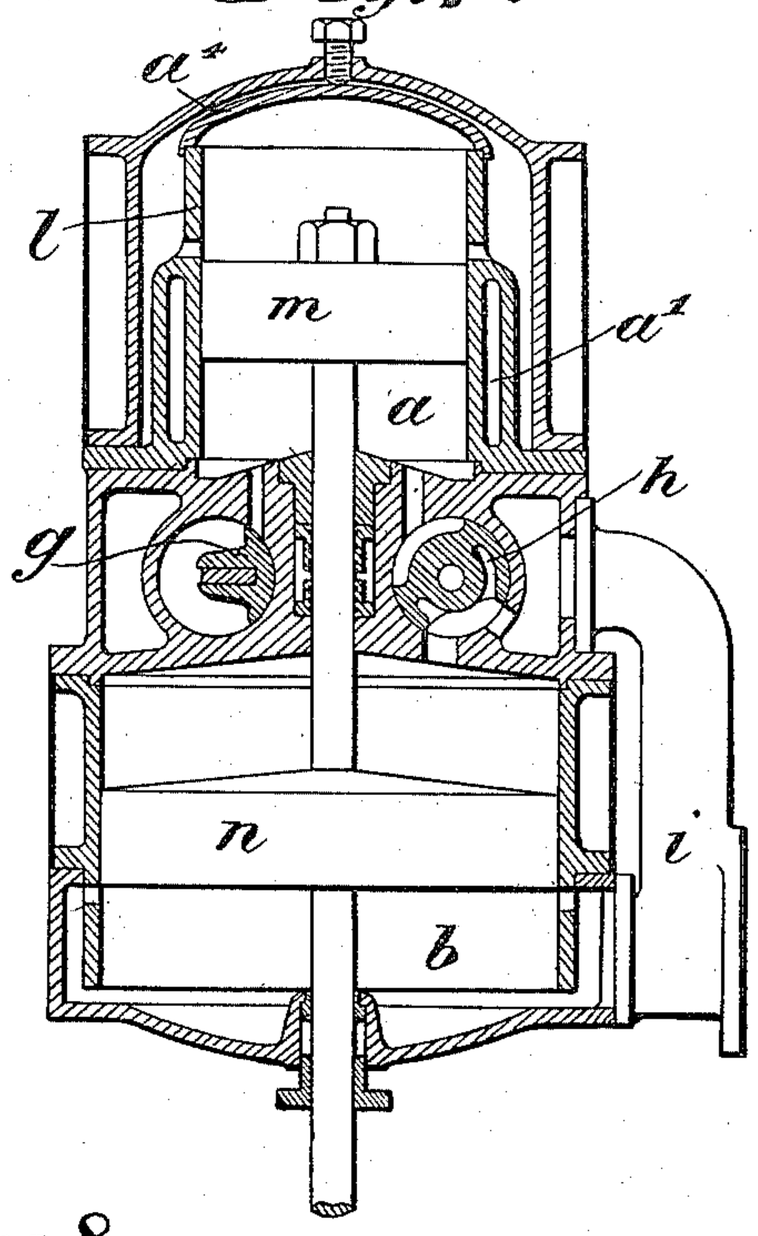
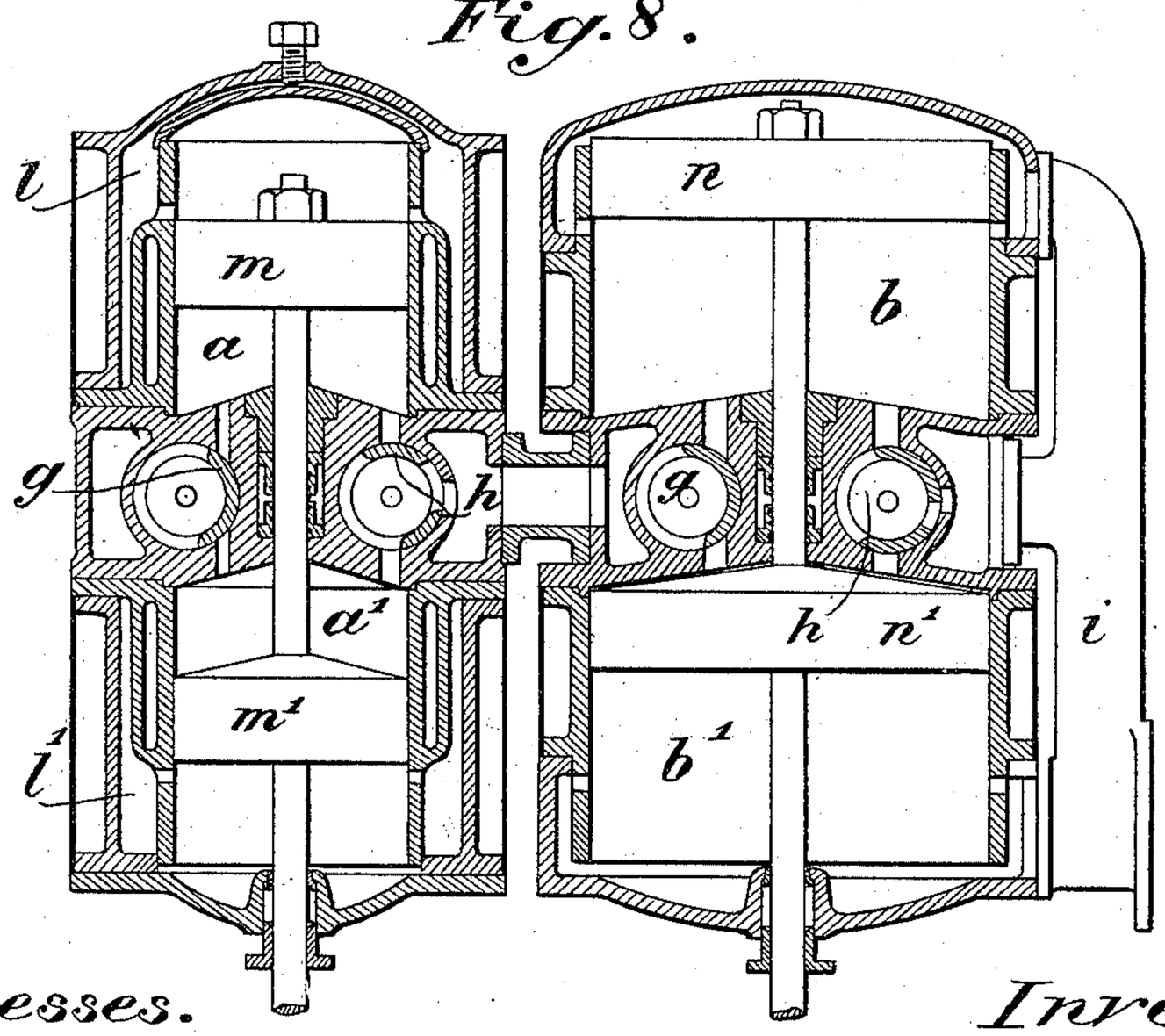


Fig. 8.



Witnesses.

James W. Berard

Geo. E. Frech.

Inventor.

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by Pattison & Neshit

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(No Model.) 5 Sheets—Sheet 5.

J. S. RAWORTH.

STEAM ENGINE.

No. 584,704. Patented June 15, 1897.

Fig. 9.

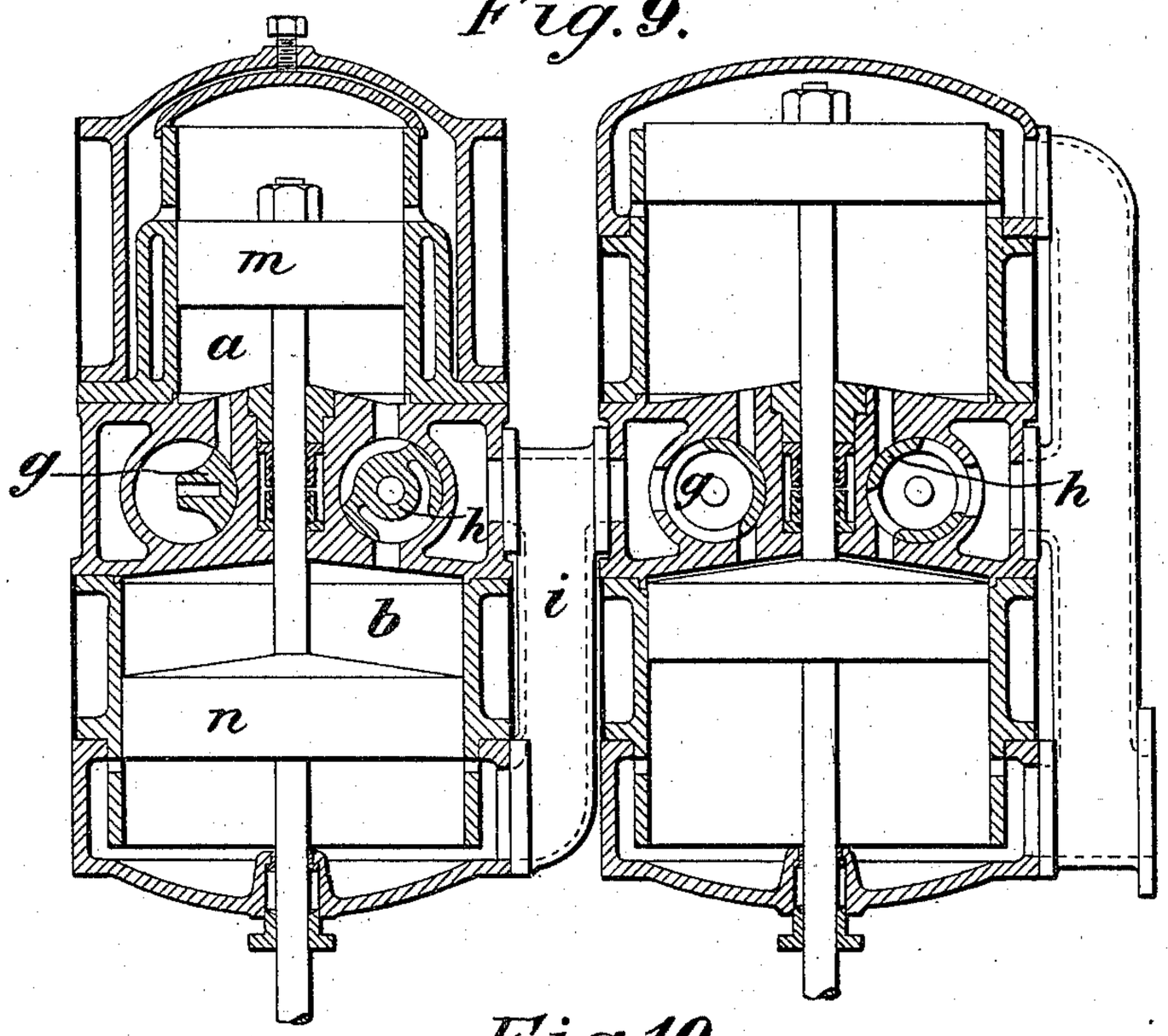
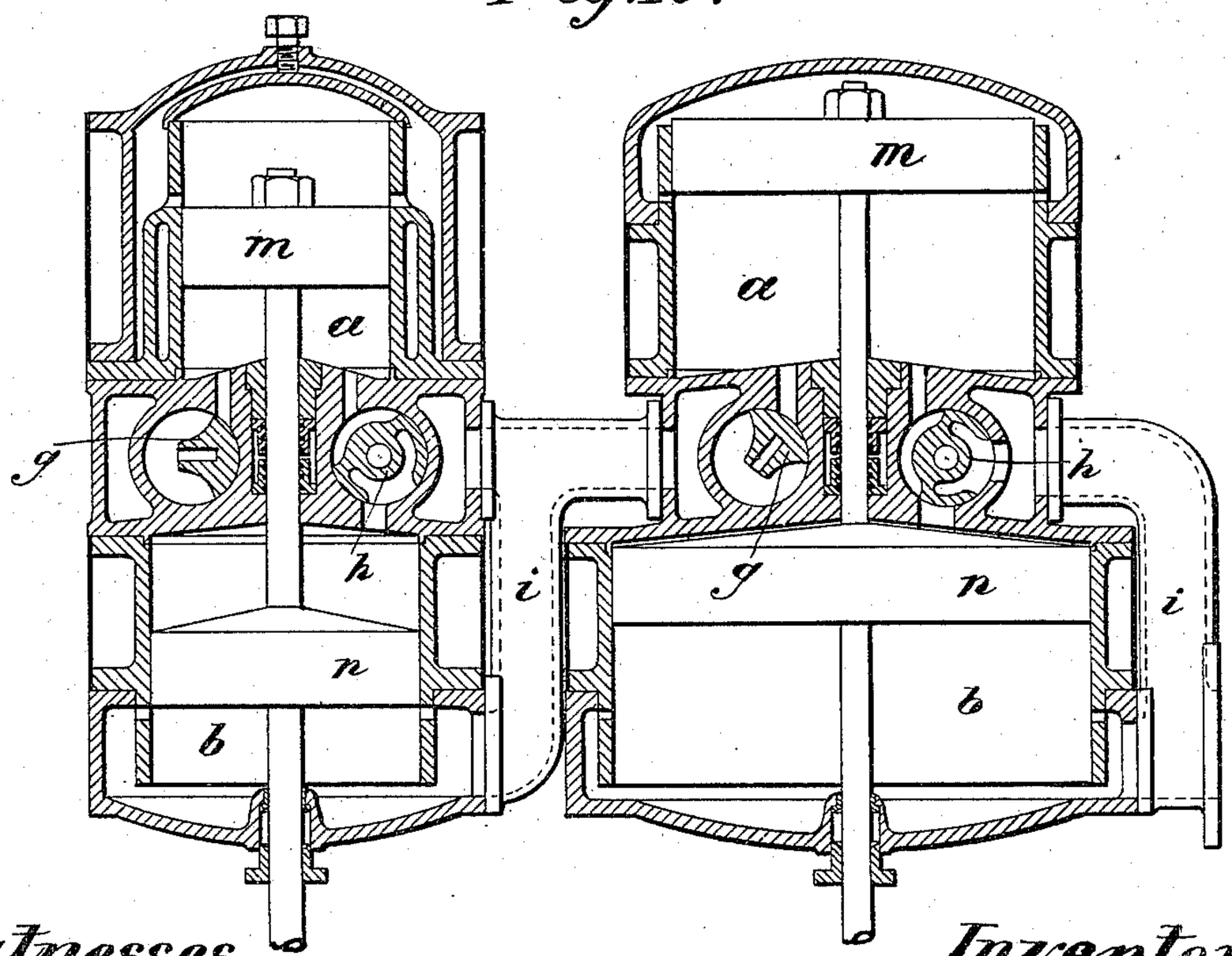


Fig. 10.



Witnesses.

Geo. E. Fitch.
James W. Brown.

Inventor:

John S. Raworth
by Pattison & Nesbit, Attys

UNITED STATES PATENT OFFICE.

JOHN SMITH RAWORTH, OF LONDON, ENGLAND.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 584,704, dated June 15, 1897.

Application filed September 23, 1895. Serial No. 563,374. (No model.) Patented in Spain January 2, 1895, No. 18,152; in England March 1, 1895, No. 4,442, and July 9, 1895, No. 24,751; in France July 9, 1895, No. 248,768; in Belgium July 22, 1895, No. 116,655; in Germany August 11, 1895, No. 86,408; in Switzerland September 6, 1895, No. 11,163; in Hungary October 27, 1895, No. 4,023; in Austria November 30, 1895, No. 4,571; in New Zealand December 10, 1895, No. 8,137; in Victoria December 11, 1895, No. 12,732; in Queensland December 12, 1895, No. 3,207; in West Australia December 12, 1895, No. 787; in New South Wales December 14, 1895, No. 6,270, and in Italy December 31, 1895, LXXIX, 219.

To all whom it may concern:

Be it known that I, JOHN SMITH RAWORTH, a subject of the Queen of Great Britain and Ireland, residing at Streatham, London, in the county of Surrey, England, have invented Improvements in Steam-Engines, of which the following is a specification, and for which patents have been granted in other countries as follows: Great Britain, No. 4,442, dated March 1, 1895, and No. 24,751, dated July 9, 1895; France, No. 248,768, dated July 9, 1895; Belgium, No. 116,655, dated July 22, 1895; Austria, No. 4,571, dated November 30, 1895; Hungary, No. 4,023, dated October 27, 1895; Germany, No. 86,408, dated August 11, 1895; Switzerland, No. 11,163, dated September 6, 1895; Spain, No. 18,152, dated January 2, 1895; Victoria, No. 12,732, dated December 11, 1895; Queensland, No. 3,207, dated December 12, 1895; New Zealand, No. 8,137, dated December 10, 1895; West Australia, No. 787, dated December 12, 1895; New South Wales, No. 6,270, dated December 14, 1895, and in Italy, Reg. Att., Vol. LXXIX, No. 219, dated December 31, 1895.

My invention has reference to improvements in steam-engines in which two or more cylinders are used in tandem. According thereto the cylinders are placed one above the other or one in front of the other, according as the engine is vertical or horizontal, and the valves are placed between the adjacent ends of the cylinders—that is to say, in compound engines the valves would be placed between the high-pressure and low-pressure cylinders, and in the case of a triple-expansion engine they would be placed between the adjacent ends of the several cylinders. By this means the clearances in the ports and passages are reduced to a minimum. I prefer to use valves of the well-known Corliss type, but similar results can be obtained with more or less efficiency with other forms of valves.

Compound engines constructed in accordance with my invention are double-acting as regards the forces transmitted by the piston-rod, but are single-acting in each cylinder—that is to say, the high-pressure steam acts upon the under side of the high-pressure piston and the expanded steam acts upon the upper side of the low-pressure piston in a vertical engine and upon the corresponding sides in a horizontal engine.

In the accompanying drawings, Figure 1 shows, partly in vertical section on the line A B of Fig. 2 and partly in elevation, a compound vertical steam-engine constructed according to this invention. Fig. 2 shows the engine in elevation, and Fig. 3 is a sectional view at right angles to Fig. 1. Figs. 4 and 5 are sections through the valve-box on the lines C D and E F, respectively, of Fig. 3, the valves and their driving mechanism being omitted. Figs. 6 to 10, inclusive, are vertical sections illustrating cylinders and valve arrangements according to this invention for engines of various types.

Referring to Figs. 1, 2, and 3, the high-pressure steam enters through the end of the valve-chamber d from the branch d' and is admitted at suitable intervals by the valve g, vibrating on its axis, through the short direct port d' to the high-pressure cylinder a, which is surrounded by a live-steam jacket a'. When the high-pressure piston arrives at the top of its stroke, it passes a ring of port-holes a^3, by means of which equilibrium is established between the steam-pressures in the cylinder a and the receiver l, which is in communication by means of the ports l' l' with a chamber or pocket l^2, formed in a partition or valve-box arranged between the adjacent inner ends of the cylinders, and in which the valve-chambers d and e are also formed, Figs. 1, 3, 4, and 5. The high-pressure piston having now arrived, as described, at the top of its stroke and the high-pressure steam-port d' having been previously closed, the low-pressure oscillating valve h will have commenced to open a passage through valve-chamber e and short direct ports e' e^2 between the high-pressure cylinder a and the low-pressure cylinder b, and also to open passages through

the said valve-chamber *e* and the ports l^3, *e'*, and e^2 between the receiver and the inner end of each cylinder, and each of these passages will remain open until the point of cut-off is reached, say one-half to three-quarters of the stroke, when the passage e^2 to the low-pressure cylinder will be closed and the steam remaining in the high-pressure cylinder will pass into the receiver *l* l^2 through the ports l^3, Figs. 4 and 5, which remain open to the high-pressure cylinder until the valve *h* closes for compression.

The low-pressure piston *n* on arriving at the bottom of its stroke passes a ring of port-holes *b'*, which allow the water and steam to pass out into the exhaust-chamber *k*, from which an outlet is provided at *i'*. On the up or return stroke of the low-pressure piston *n* an outlet for the steam remaining above the piston is provided through the pipe *i* by the exhaust-cavity of the valve *h* covering the two ports e^2 e^3.

The valves *g* and *h* are driven by levers fixed to the ends of their spindles, from eccentrics and rods, as shown in the drawings, or by any other well-known method suitable for the size and speed of the engine.

The method of governing shown in Figs. 2 and 3 is by means of a centrifugal governor carried by the crank-shaft and arranged to vary the throw of the eccentric used for driving the valve *g*, but an ordinary throttle-valve acting upon the steam-inlet may be used, if required.

During the downstroke of the high-pressure piston steam from the receiver *l* obtains access to the top side of the piston *m*. In non-condensing engines this communication may be constant through holes in the cover a^4, but in condensing-engines it is better to make it intermittent through the port-holes a^3, as shown.

The steam-jacket *a'* is supplied with live steam through a small port a^2, communicating with the valve-chamber *d*, and the condensed water is collected at each stroke in a small pocket in the low-pressure valve *h*, being fed thereto by a similar port to a^2, and by the motion of the valve carried round and discharged through a small port leading into the exhaust-cavity e^5. These ports and the corresponding pocket in the valve are merely drilled holes and are too small to be visible in the drawings. A relief-valve l^4 is placed in the head of the low-pressure cylinder to discharge water or excessive steam-pressure to the receiver *l* l^2.

The cylinders are carried on a hollow truncated conical frame *t*, which for small engines may be cast in one piece, but for large engines may be built up in any convenient and suitable manner. This frame, which is provided with large openings for examination and repair of the engine, is closed in by a sheet-metal apron *t'*, which retains the oil and returns it to the crank-chamber *x*, which forms part of the base-plate upon which the engine is built.

The crank-shaft bearings, which are of ordinary construction, are held down by wedge-pieces *v* *v'* and tightening-screws v^2. The upper wedge-piece *v'* slides in horizontal slots cut in the sides of the bearing-seat. The lubrication is effected by a small pump which draws oil from the crank-chamber and delivers it to the valve-spindle bearings and joints at *f*, whence it descends by the hollow eccentric-rods to the eccentrics and by small pipes to the low-pressure gland *s*, and thence to the cross-head pin and guide.

Engines of various types, vertical, horizontal, or inclined, can be constructed with cylinders arranged in tandem with valves placed between them in the manner above set forth.

Figs. 6 to 10, inclusive, are vertical sections illustrating the cylinder and valve arrangements of several constructions.

Fig. 6 shows parts of a simple engine having two single-acting high-pressure pistons *m* *m'*, to the inner ends of which steam is alternately admitted from the valve-chamber *d* through short direct ports *d'* d^2 by the cut-off valve *g*, the exhaust-valve *h* serving to place each cylinder in turn in communication with the exhaust-pipe *i* through the valve-chamber *e*. In this case the outer ends of the cylinders *a* *a'* are closed, so that the same fluid—for example, air—remains constantly therein, or they may have open ends communicating with the exhaust-pipe, as shown on the right-hand side of Fig. 9. The valve-chambers are formed in a partition arranged between the inner ends of the cylinders, as in the arrangement shown in Figs. 1 to 5, inclusive, but there is no receiver in this case.

Fig. 7 shows parts of the arrangement represented in Figs. 1 to 5, inclusive, and is placed here in juxtaposition to the others for the purpose of facilitating comparison.

Fig. 8 shows parts of a compound engine consisting of two simple engines, of which the left hand one has two high-pressure pistons *m* *m'*, as in Fig. 6, and exhausts into the right-hand one, which finally exhausts into the pipe *i*, the two high-pressure cylinders *a* *a'* being steam-jacketed and provided with receivers *l* *l'*, like the cylinder *a* in Fig. 7, and the outer ends of the two low-pressure cylinders *b* *b* being in communication with the exhaust-pipe *i*, like the outer end of the cylinder *b* in Fig. 7. In this arrangement while high-pressure steam is being admitted into and is expanding in cylinder *a*, that which has already done duty in cylinder *a'* is permitted by the valve *h* of the high-pressure engine to pass partly into the valve-chamber *d* of the low-pressure engine and thence by valve *g* therein to the low-pressure cylinder *b'* and partly to the receiver *l'* of the cylinder *a'*, the steam that has already done duty in cylinder *b* escaping past the valve *h* of the low-pressure engine to the

exhaust i'. Similarly when high-pressure steam is admitted to the cylinder a' that which has done duty in cylinder a passes partly to the receiver l of that cylinder and partly to the cylinder b, while that in cylinder b' will be passing to the exhaust i.

Fig. 9 shows parts of a triple-expansion engine composed of a compound engine constructed and operating like that shown in Figs. 1 to 5, inclusive, exhausting into a simple engine like that shown at the right-hand side of Fig. 8.

Fig. 10 shows parts of a quadruple-expansion engine consisting of two compound engines constructed and operating like that shown in Figs. 1 to 5, inclusive, arranged in series, the several pistons being of gradually-increasing size.

What I claim is—

1. A compound steam-engine comprising high and low pressure cylinders arranged tandemwise, an interposed partition, two independent valve-chambers formed in said partition, the one being in communication with a steam-supply and the other with an exhaust, a short direct passage through said partition from the inner end of the high-pressure cylinder to the valve-chamber connected with the steam-supply and a short direct passage from the inner end of each of said cylinders to the other valve-chamber and in each valve-chamber a valve, said valves being independent of each other and adapted the one to admit high-pressure steam into the high-pressure cylinder at its inner end and the other to establish communication at the proper time between the high-pressure cylinder and the low-pressure cylinder and afterward between the low-pressure cylinder and the exhaust.

2. A compound steam-engine comprising high and low pressure cylinders arranged tandemwise, a receiver, communication between the receiver and the outer end of the high-pressure cylinder, a partition interposed between the two cylinders, a valve-chamber formed in said partition and which is in communication with the supply of high-pressure steam and with the inner end of the high-pressure cylinder, a valve adapted to control said communication, a second valve-chamber also formed in said partition independently of the other and which has communications between it and the inner end of the high-pressure cylinder, the inner end of the low-pressure cylinder, the receiver, and the exhaust, and an independent valve located in said last-mentioned valve-chamber and adapted to, at the proper time, place the inner end of the high-pressure cylinder in communication with the low-pressure cylinder and for a time to place the inner ends of both these cylinders in communication with the receiver and subsequently to close the communication between the low-pressure cylinder and the receiver and to open communication between the low-pressure cylinder and the exhaust.

3. A steam-engine comprising two cylinders arranged tandemwise, a partition arranged between the adjacent ends of said cylinders and formed with independent cylindrical valve-chambers having their axes at right angles to those of said cylinders and with short direct passages connecting the inner ends of said cylinders with said valve-chambers, independent oscillating cylindrical steam and exhaust valves located within said valve-chambers and adapted to control the communication between the same and the adjacent ends of the said cylinders, and means for operating said valves, substantially as herein described.

4. In a steam-engine, two cylinders arranged tandemwise, a partition arranged between and transversely to the adjacent ends of said cylinder and formed with independent cylindrical valve-chambers having their axes at right angles to those of said cylinders, one of said valve-chambers being in communication with the steam-supply and the other with an exhaust, short direct passages through said partition from the inner end of each of said cylinders to each valve-chamber and a valve in each of said chambers, said valves being independent of each other and adapted the one to admit steam to the inner end of each cylinder alternately and the other to place the inner end of each cylinder alternately in communication with the exhaust.

5. A steam-engine comprising two cylinders arranged tandemwise, a partition arranged between and transversely to the adjacent ends of said cylinders and formed with independent cylindrical steam and exhaust valve chambers having their axes at right angles to those of said cylinders, independent cylindrical cut-off and exhaust valves located in said chambers, short direct passages connecting each valve-chamber with the inner ends of the two cylinders, and a passage connecting the exhaust-valve chamber with an exhaust-pipe, said passages being arranged to be controlled by the corresponding valves, substantially as described.

6. A compound single-acting steam-engine comprising a high-pressure cylinder, a low-pressure cylinder, a partition arranged between the adjacent ends of said cylinders and formed with separate cylindrical valve-chambers one of which is connected with the inner end of the high-pressure cylinder and the other with the inner end of each cylinder, an independent cylindrical valve adapted to control the passage of high-pressure steam from one valve-chamber to the inner end of the high-pressure cylinder, an independent cylindrical valve adapted to control the passage of steam from the inner end of the high-pressure cylinder to the corresponding end of the low-pressure cylinder and from the latter cylinder to the exhaust, and means for oscillating said valves, substantially as herein described.

7. A compound single-acting engine comprising a high-pressure cylinder and a low-

pressure cylinder arranged tandemwise, a partition located between the adjacent ends of said cylinders and formed with two independent valve-chambers one of which communicates through a short direct port with the high-pressure cylinder and the other through short direct ports with both cylinders, independent cylindrical valves located within said chambers and arranged to control said ports and a receiver formed partly by a chamber in said partition and partly by a casing surrounding said high-pressure cylinder, said receiver being adapted to communicate with the outer end of the high-pressure cylinder through holes in the wall thereof and with the inner end of each cylinder through ports controlled by one of said valves, substantially as herein described for the purpose specified.

8. A steam-engine comprising a high-pressure cylinder a having ports a^3 in the outer end portion of its wall, a low-pressure cylinder b arranged in tandem with said cylinder a and formed with exit-ports h' near its outer end, connected pistons working in said cylinders, a partition arranged between said cylinders and formed with cylindrical valve-chambers d and e, ports d', e', e^2, e^3 and b^3, exhaust-cavity e^5 and pockets b^2 a receiver l surrounding said high-pressure cylinder and in communication with said ports a^3 and with said pockets, a cylindrical high-pressure valve g controlling said port d', a cylindrical low-pressure valve h controlling said ports e', e^2, e^3, and b^3, means for oscillating each of said valves, and an exhaust-pipe communicating with said exhaust-cavity e^5 and ports b', substantially as described for the purpose specified.

9. A single-acting compound steam-engine comprising a high-pressure cylinder a having a steam-jacket a', perforations a^3, and piston m, a low-pressure cylinder b arranged tandemwise with regard to said cylinder a and provided with a row of perforations b', and a piston n connected to said piston m and to the crank-shaft of the engine, a valve-box located between the adjacent ends of said cylinders and provided with steam-chambers d and e, pockets l^2 and steam-ports a^2, d', e', e^2, e^3, l^3, and e^5, and a relief-valve l^4, and oscillating valve g arranged in chamber d and adapted to control port d', an oscillating valve h arranged in chamber e and adapted to control ports e', e^2, e^3, and l^3, means for operating said valves, a steam-receiver l surrounding said high-pressure cylinder and communicating with said pockets l^2 by ports l', an exhaust-chamber k into which the perforated lower or outer end of said cylinder b extends, and an exhaust-pipe i in communication with said port e^5 and chamber k, all substantially as herein described for the purpose specified.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

JOHN SMITH RAWORTH.

Witnesses:
EDMUND S. SNEWIN,
WM. O. BROWN.